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Efficient propagation of electromagnetic pulses through high-power solid state laser amplifiers

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There is currently a lack of broadly available modeling software that self-consistently captures the required physics of gain, thermal loading and lensing, spectral shaping, and other effects required to simulate and optimize high-intensity lasers (100 TW to multi-PW) with ultra-short pulse lengths (< 100 fs) [1]. In recent work [2], we showed that low-resolution wavefront sensor (WFS) images could be used to construct native SRW [3] wavefront objects. We propagate these general 2D wavefronts via linear canonical transforms (LCT) [4], using the decomposition of Pei and Huang [5] to recast a standard ABCD matrix into three, each of which SRW can use to transform the wavefront with physical optics. We present an operator splitting approach, which divides both the crystal and the amplified laser pulse into slices, so that the algorithms remain 2D for an intrinsically 3D problem. We also discuss work on a new Python library for LCTs, which will enable wavefront propagation via more general ABCD matrices. Comparisons with experimental data are presented.

[1] R. Falcone et al., Brightest Light Initiative Workshop Report: the Future of Intense Ultrafast Lasers in the U.S. (2020), doi:10.2172/1604161

[2] D.L. Bruhwiler et al., "Open source software to simulate Ti:Sapphire amplifiers," in Proc. Int. Part. Accel. Conf., THPOTK063 (2022); https://accelconf.web.cern.ch/ipac2022/papers/thpotk063.pdf

[3] O. Chubar, Synchrotron Radiation Workshop (SRW), https://github.com/ochubar/srw

[4] J. Healy, M. Kutay, H. Ozaktas, and J. Sheridan, Linear Canonical Transforms: Theory and Applications (2016), doi:10.1007/978-1-4939-3028-9

[5] S.-C. Pei and S.-G. Huang, "Two-dimensional nonseparable discrete linear canonical transform based on cm-cc-cm-cc decomposition," J. Opt. Soc. Am. A 33, p. 214 (2016), doi:10.1364/JOSAA.33.000214

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